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(54) Abstract Title

Circuit arrangement for producing frequency signals

(57) In a circuit arrangement for generating at least two signals of different frequencies at least one pair of frequencies having closely adjacent frequencies  $f_1$  and  $f_1'$ ,  $f_2$  and  $f_2'$ ,  $f_3$  and  $f_3'$  are derived from a frequency oscillator having a fundamental pulse  $f_0$ , 52. The circuit may be used to generate modulation frequencies of laser signals 16 for a distance measuring instrument 10. A trigger signal  $f_5$  from a microprocessor 50 is used to generate the different adjacent frequencies. At least one frequency is generated by filtering harmonics from at least one frequency  $f_{10}$ ,  $f_{20}$ ,  $f_{30}$ ,  $f_{10}'$ ,  $f_{20}'$ ,  $f_{30}'$  derived from the fundamental pulse  $f_0$ , 52. The circuit includes switchable splitters 28, 34 controlled by the microprocessor 50 and having sub-splitters (76, 78, 80, 82 Fig 2) and switching means (74, 80, 82, 92). The splitter 34 has shift elements (88, 90).

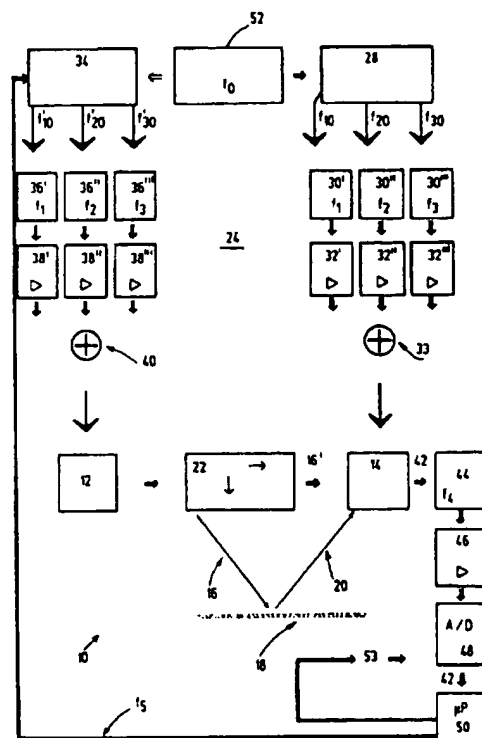


Fig.1

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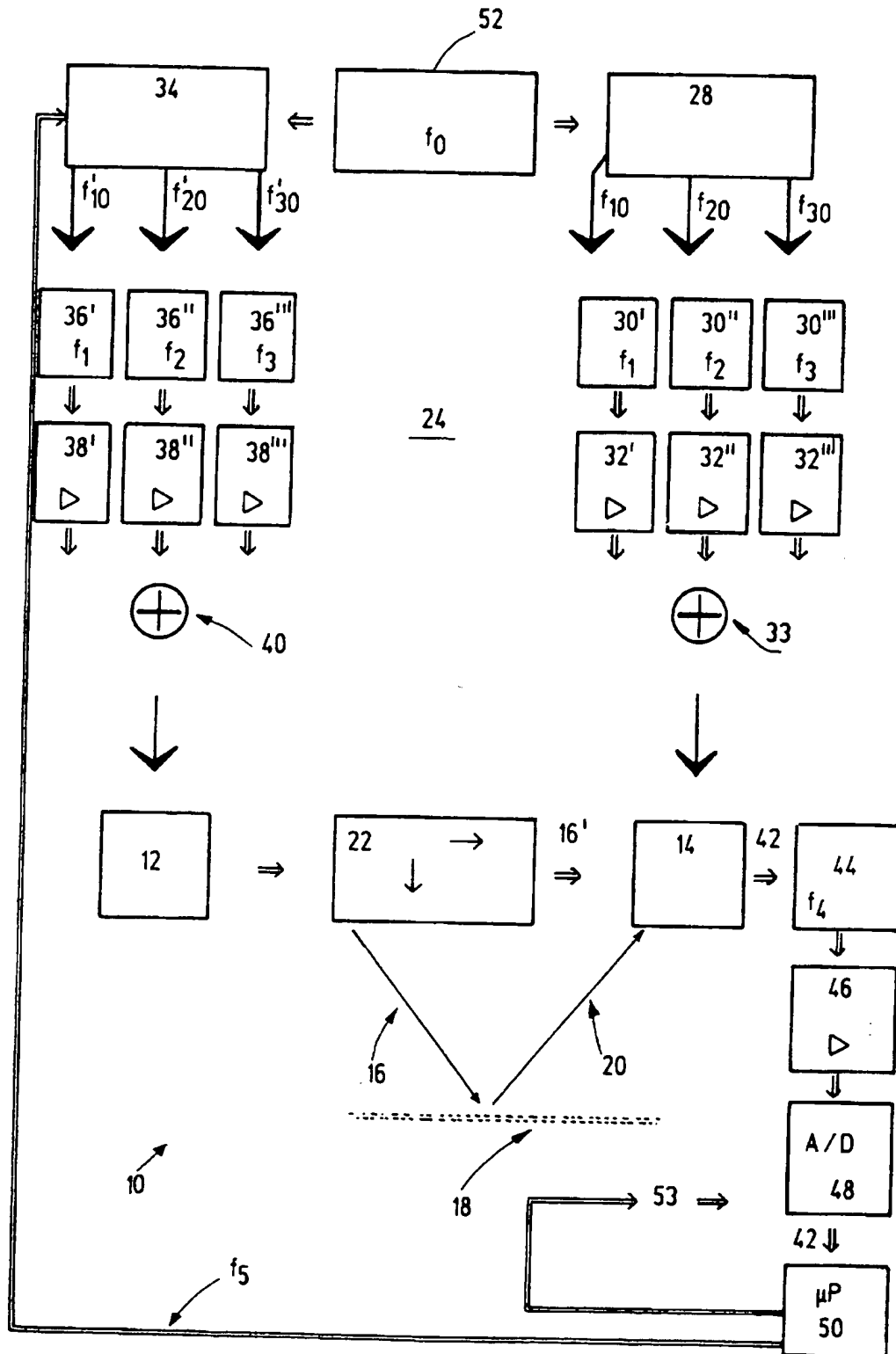


Fig. 1

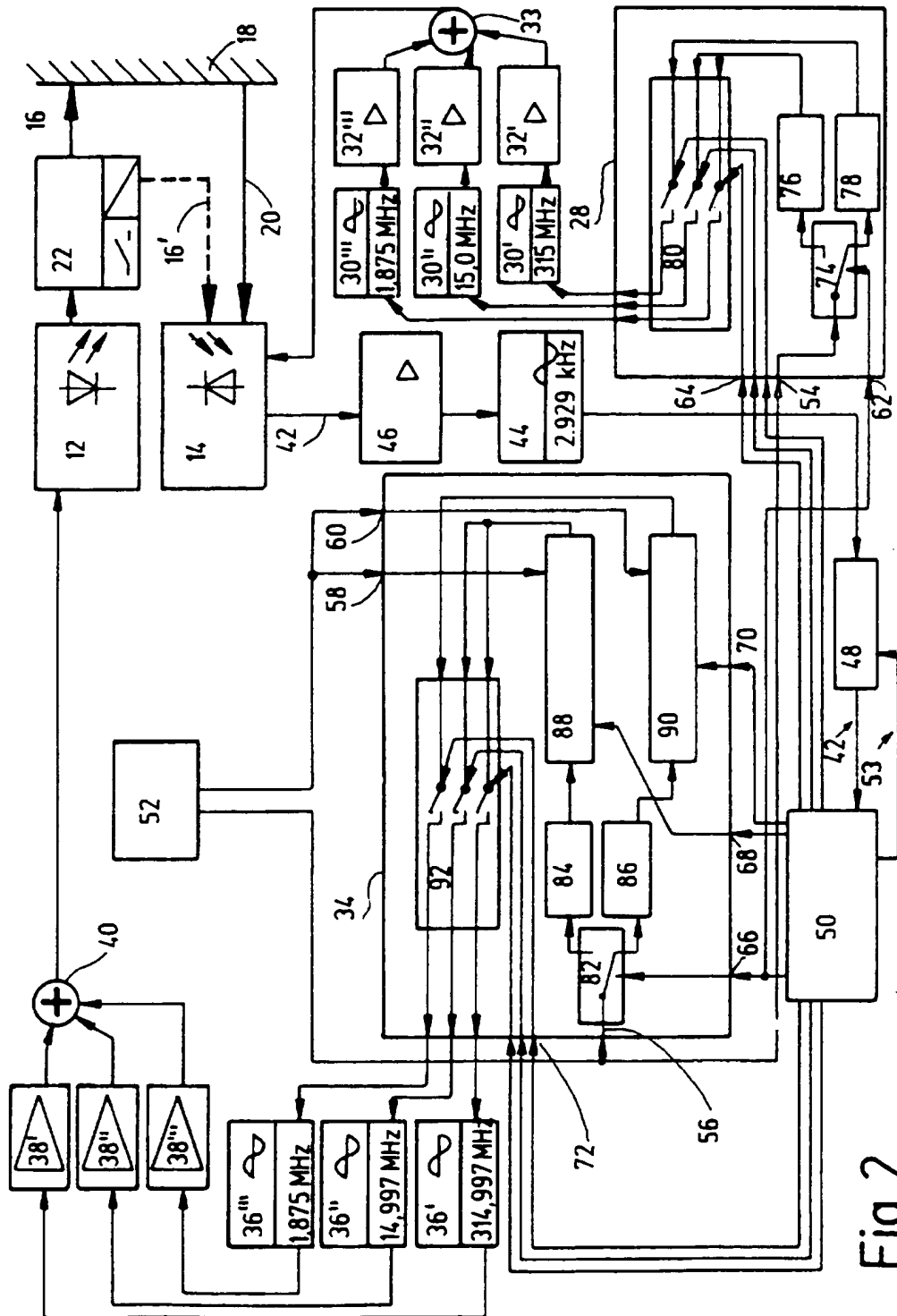


Fig. 2

5

### Circuit arrangement for producing frequency signals

The present invention relates to a circuit arrangement for producing at least two signals of different frequency.

10

### Prior art

Generic circuit arrangements are used for example in devices for measuring the distance of an object by means of  
15 a collimated laser beam. Such measuring instruments operate inter alia according to a phase difference method, a phase angle between an emitted light beam and a received light beam reflected by an object being evaluated in order to determine the distance between the measuring instrument  
20 and the said object. The phase angle is proportional to the distance of the object from the measuring instrument. In order to achieve a high measurement accuracy, it is known to select the measurement frequencies to be as large as possible. Since however unambiguous measurements can be  
25 obtained only for a phase angle between  $0^\circ$  and  $360^\circ$ , it is known from DE 43 03 804 A1 to alternate a high modulation frequency of the emitted light beam with at least one further, substantially lower modulation frequency of the emitted light beam in order thereby to achieve a  
30 measurement range over the phase angle range from  $0^\circ$  to  $360^\circ$  of the high modulation frequency.

It is also known, in order to achieve a phase difference between the emitted and the received signals, to transform  
35 the latter to a lower frequency by mixing, the basic information, namely the phase shift between the emitted and received signals, being maintained. In order to achieve this mixing of a measurement frequency, it is known to mix the emitted and/or received signals with a signal whose

frequency is shifted so slightly that the resulting mixed signal lies in the low frequency range, where the phase can be measured without any problem. In order to generate the different frequency signals required for this purpose, the  
5 known circuit arrangements include a corresponding number of frequency oscillators. The associated circuitry and control devices are relatively complicated, and even the slightest calibration error between the individual oscillators can lead to variations in the signal and thus  
10 in the end result.

#### Advantages of the invention

The circuit arrangement according to the invention having  
15 the features disclosed in claim 1 provides the advantage that different frequencies can be generated in a simple manner with a high degree of accuracy. Since various frequencies can be derived digitally from an individual frequency oscillator (basic pulse oscillator), all these  
20 frequencies have the same relative accuracy as the basic pulse oscillator. The circuit arrangement according to the invention advantageously generates harmonics. Further, very high frequencies having the same stability as the basic pulse oscillator are formed therefrom using narrow-  
25 band filters, for example a surface wave filter, frequencies above 100 MHz thereby being possible. A further advantage is that if two of the frequencies derived from the basic pulse oscillator are mixed together, then the low-frequency mixed product is just as stable as the basic  
30 pulse oscillator, and moreover without any post-regulation at all. Since all required frequencies are derived simply from a basic pulse oscillator, a frequency error between the individual signals of different frequencies is excluded since these all originate jointly from a fundamental  
35 frequency of an oscillator. This is made possible by the fact that the different frequencies are generated purely digitally by synthetic frequency shifting and/or splitting.

The generated harmonics are likewise synthetically, i.e. purely digitally shifted, with the result that they have the same accuracy as the basic pulse oscillator. Even the slightest frequency differences between the individual  
5 frequency signals as a result of different origins (several oscillators), leading to variations, are thus reliably avoided. The measuring procedure is accordingly simpler and more accurate. Pairs of frequencies having very close frequencies can thus be produced, very close in this  
10 context denoting a frequency difference that cannot be produced from an output frequency by splitting.

Further advantageous modifications of the invention are provided by the remaining features, disclosed in the  
15 subclaims.

#### Drawings

The invention is described in more detail hereinafter by  
20 means of an embodiment and with the aid of the accompanying drawings, in which:

Fig. 1 is a schematic diagram of a laser-operated distance measuring instrument, and  
25 Fig. 2 is a block circuit diagram of a laser-operated distance measuring instrument.

#### Description of the embodiment

30 Every signal  $S$  that is not permanently locked onto a d.c. value is identified hereinafter by the frequency  $f$ . The signal  $S$  can be sinusoidal, square-wave, or for a limited time sinusoidal and/or square-wave. If the signal  $S$  is square-wave, then in addition to the fundamental frequency  
35  $f$  further frequencies, so-called harmonics, are also formed. The theory associated with this is known from mathematics and will not be described in more detail here.

If the signal is sinusoidal and/or square-wave only for a limited time, as is the case inter alia with signals that are phase shifted in a regular time sequence by a constant phase angle, then the signal is also termed a frequency.

- 5 The numerical value  $f$  in this case denotes that frequency in the frequency spectrum that occurs with the largest amplitude. In this case frequencies may arise that are not a multiple of the frequency  $f$ . Such frequencies are hereinafter also termed harmonics.

10

Fig. 1 is a diagram of a distance measuring instrument identified overall by the reference numeral 10. The instrument comprises a light emitter 12, for example a laser diode, as well as a light receiver 14, for example a  
15 photodiode. A collimated, visible continuous laser beam that is visible at an object 18 (hereinafter also called target) is generated as an emitted signal 16 by means of the light emitter 12. The emitted signal is reflected by the object 18 according to the laws of optics and is  
20 received as a received signal 20 by the light receiver 14. The emitted signal 16 is passed as a reference signal 16' to the light receiver 14 immediately after the target measurement, via an optical reversing switch 22, for example a movable shutter.

25

A circuit arrangement 24 is provided to control the distance measuring instrument 10. This arrangement includes a quartz oscillator 52. The quartz oscillator 52 generates a fundamental frequency  $f_0$  (fundamental pulse 52, Fig. 2),  
30 from which are derived all the frequencies, described in more detail hereinafter, involved in the operation of the distance measuring instrument 10. In order to improve the certainty range of the distance measurement using the distance measuring instrument 10, the latter is operated  
35 with a total of three modulation frequencies for the emitted signal 16. The emitted signal 16 itself is amplitude-modulated in a manner known per se. The received

signal is consequently also amplitude-modulated in the same way. Since the optical reversing switch is switched over at a known point in time, then on the basis of the time sequence it can be unambiguously established whether the  
 5 instantaneous optical received signal comes directly from the optical reversing switch or from the target. The light receiver 14 is designed as an avalanche photodiode known per se, and permits several frequencies to be mixed simultaneously. The design, construction and mode of  
 10 operation of such an avalanche photodiode are known, and accordingly will not be described in more detail within the scope of the present description.

A first switchable splitter 28 is associated with the  
 15 quartz oscillator 52, by means of which splitter the frequency  $f_0$  generated by the quartz oscillator 52 can be split further as desired into a frequency  $f_{10}$ , a frequency  $f_{20}$  as well as a frequency  $f_{30}$ . The frequencies  $f_{10}$ ,  $f_{20}$ ,  $f_{30}$  can adopt each value achievable by splitting. Also, at  
 20 least two of the frequencies may be identical. This is useful for example if harmonics of at least one of the frequencies  $f_{10}$ ,  $f_{20}$ , or  $f_{30}$  are filtered out in the connected band-pass filters 32', 32'' and 32'''. Filters 30, designed as band-pass filters 30' for the frequency  $f_1$ , 30''  
 25 for the frequency  $f_2$  and 30''' for the frequency  $f_3$ , are connected to the splitter 28. The following relationship applies as regards the frequencies  $f_{10}$ ,  $f_{20}$ ,  $f_{30}$ ,  $f_1$ ,  $f_2$ , and  $f_3$ :

$$\begin{aligned} 30 \quad f_1 &= k' * f_{10} \\ f_2 &= k'' * f_{20} \\ f_3 &= k''' * f_{30} \end{aligned}$$

$k', k'', k''' \in 1 \dots N$ ; (N is an arbitrary large number).

35

Amplifiers 32 are connected to the filters 30, an amplifier 32' being designed for signals of frequency  $f_1$ , an amplifier



32'' for signals of frequency  $f_2$ , and an amplifier 32''' for signals of frequency  $f_3$ . The amplified signals of frequency  $f_1$ ,  $f_2$  and  $f_3$  are passed through a summing element 33 to the light receiver 14.

5

A second switchable splitter with an additional digital circuit arrangement 34 is associated with the quartz oscillator 52. Signals of frequencies  $f_{10}'$ ,  $f_{20}'$  and  $f_{30}'$  can be fed to the output of the splitter 34. The frequencies  
 10  $f_{10}'$ ,  $f_{20}'$  and  $f_{30}'$  are reswitched as regards their phase with a frequency  $f_s$  by means of the digital circuit arrangement 34. A mixture of several frequency lines is produced in this way in the frequency spectrum. At least two of the frequencies  $f_{10}'$ ,  $f_{20}'$  and  $f_{30}'$  may be identical. This is  
 15 useful for example if harmonics from at least one of the frequencies  $f_{10}'$ ,  $f_{20}'$  or  $f_{30}'$  are filtered out in the connected band-pass filters 36', 36'' and 36'''. Band-pass filters 36 are associated with the splitter 34, a filter 36' being designed for signals of frequency  $f_1'$ , a  
 20 filter 36'' for signals of frequency  $f_2'$ , and a filter 36''' for signals of frequency  $f_3'$ .

Amplifiers 38 are connected to the filters 36, an amplifier 38' being designed for signals of frequency  $f_1'$ , an  
 25 amplifier 38'' for signals of frequency  $f_2'$ , and an amplifier 38''' for signals of frequency  $f_3'$ . The amplified signals of frequencies  $f_1'$ ,  $f_2'$  and  $f_3'$  are passed through a summing element 33 to the light emitter 12. The emitted signal 16 is modulated by means of the light emitter 12  
 30 according to the switched-through frequency  $f_1'$ ,  $f_2'''$  and  $f_3'''$ .

The light receiver 14 receives a time-spaced succession of optical signals denoted hereinafter by A, and with each  
 35 optical signal simultaneously receives the electrical signal denoted hereinafter by B:

	List A of optical signals	List B of associated electrical signals
	- target signal 20 of frequency $f_1'$ .....	Mixed signal of frequency $f_1$
5	- target signal 20 of frequency $f_2'$ .....	Mixed signal of frequency $f_2$
	- target signal 20 of frequency $f_3'$ .....	Mixed signal of frequency $f_3$
10	- reference signal 16' of frequency $f_1'$ .....	Mixed signal of frequency $f_1$
	- reference signal 16' of frequency $f_2'$ .....	Mixed signal of frequency $f_2$
	- reference signal 16' of frequency $f_3'$ .....	Mixed signal of frequency $f_3$
15		

A transformation by mixing to produce an evaluation signal 42 is achieved hereby. This evaluation signal 42 contains the required basic information, namely the phase angle of the target signal 20 in relation to a A/D transducer pulse 53 on the one hand and, in time succession, the phase angle of the reference signal 16' in relation to the A/D transducer pulse on the other hand. The reference quantity is derived from the difference in the two phase angles per measurement frequency, since it remains unaltered in all subsequent measurements. The result is a phase angle per measurement frequency pair  $f_1'-f_1$ ,  $f_2'-f_2$  and  $f_3'-f_3$ , i.e. a total of three phase angles. The smallest frequency of the frequencies  $f_1'$ ,  $f_2'$  and  $f_3'$  determines the certainty range of the overall distance measurement. The largest frequency of the frequencies  $f_1'$ ,  $f_2'$  and  $f_3'$  determines the maximum possible measurement accuracy for a given measurement time. The frequency from  $f_1'$ ,  $f_2'$  and  $f_3'$  lying between the largest and smallest frequencies is in principle not necessary. It is however advantageously used if the measurement accuracy of the smallest frequency is not sufficient to allocate the measurement result of the

largest frequency to the correct range in each case. This is necessary in order to be able to measure distances that are greater than the certainty range of the highest frequency.

5

The frequency  $f_1$  is chosen to be relatively small in order to use a slow A/D transducer having a high resolution. The evaluation signal 42 is fed through an anti-aliasing filter 44, which forms a band-pass filter for the evaluation  
 10 signal of frequency  $f_1$ , and from there is led through an amplifier 46 to an analog-digital transducer 48. The converted evaluation signal 42 is passed to a microprocessor 50 that includes the appropriate computing, storage, counting facilities, etc., for determining the  
 15 distance of the object 18 from the distance measuring instrument 10. The transducer pulse 53 for controlling the analog-digital transducer 48 is generated at the same time via the microprocessor 50. In addition a frequency signal  $f_3$  (trigger signal) of the microprocessor 50 that is in an  
 20 at least timewise fixed relationship to the transducer pulse 53 is utilised to shift the frequencies  $f_{10}$ ,  $f_{20}$  and  $f_{30}$  to the frequencies  $f_{10}'$ ,  $f_{20}'$  and  $f_{30}'$ .

The generation of the frequencies  $f_{10}$ ,  $f_{20}$ ,  $f_{30}$ ,  $f_{10}'$ ,  $f_{20}'$ , as  
 25 well as  $f_{30}'$  is explained in more detail hereinafter with the aid of Fig. 2, which in the form of a block circuit diagram of the measuring instrument 10 shows in particular the circuit arrangement 24. Parts that are identical to those in Fig. 1 are given the same reference numerals and  
 30 will not be described again.

The shift of the frequencies  $f_1$ ,  $f_2$  and  $f_3$  by the frequency  $f_4$  to the frequencies  $f_1'$ ,  $f_2'$  as well as  $f_3'$ , and the generation of the frequencies  $f_1$ ,  $f_2$ ,  $f_3$ ,  $f_1'$ ,  $f_2'$  as well as  
 35  $f_3'$  from the frequencies  $f_{10}$ ,  $f_{20}$ ,  $f_{30}$ ,  $f_{10}'$ ,  $f_{20}'$  as well as  $f_{30}'$ , are illustrated in particular on the basis of Fig. 2. In the embodiment it is assumed that the frequency  $f_{10}$  is

15 MHz, the frequency  $f_{10}$  is 15 MHz, the frequency  $f_{10}$  is 1,875 MHz, the frequency  $f_1$  is 315 MHz, the frequency  $f_2$  is 50 MHz, and the frequency  $f_3$  is 1.875 MHz.

5 The frequency  $f_4$  by which the frequencies  $f_1$ ,  $f_2$  and  $f_3$  are shifted is 2.929 kHz, so that the frequency  $f_1'$  is 314.997 MHz, the frequency  $f_2'$  is 14.997 MHz and the frequency  $f_3'$  (sic) is 1.872 MHz. All frequencies are digitally generated by means of the trigger signal of  
 10 frequency  $f_5$  from the microprocessor 50. In the example it is assumed that the trigger signal  $f_5$  at the frequency  $f_1$  of 315 MHz and at the frequency  $f_2$  of 15 MHz is exactly four times the frequency of  $f_4$ . At the frequency  $f_3$  of 1.875 MHz the trigger signal  $f_5$  is 32 times the frequency of  $f_4$ . In  
 15 the example the quartz oscillator 52 has the frequency  $f_0 = 60$  MHz. Obviously other frequencies are also possible according to further embodiments.

The microprocessor is pulsed by a separate frequency  
 20 oscillator whose function is however subordinate and is therefore not shown. The processor pulse may advantageously also be generated by splitting  $f_0$ .

The fundamental pulse 52 is fed to an input 54 of the  
 25 splitter 58, and to an input 56 as well as inputs 58 and 60 of the splitter 34. In addition the microprocessor 50 is connected to inputs 62 as well as 64 (triple input) of the splitter 28, and to inputs 66, 6 and 70 as well as 72 (triple input) of the splitter 34.

30

The splitter 28 has a switching means 74 whose input is connected to the input 54 and whose switching outputs are connected to a splitter 76 and to a splitter 78. The splitters 76 and 78 are connected to a switching means 80,  
 35 designed as a triple on-off switch. The three switching outputs of the switching means 80 are each connected to one of the filters 30', 30'' and 30''', while the splitter 78

is connected to one switching input and the splitter 76 to two switching inputs of the switching means 80.

The switching means 74 and 80 are controlled via switching  
5 signals generated by the microprocessor 50 at the inputs 62 and 64 respectively, the switching means 74 being able to be switched over to one of its two switching positions, and the switching means 80 being able to be switched on with one of its three switching elements. The splitter 76  
10 splits the frequency  $f_0$ , of the fundamental pulse 52 fed through the input 54, by a factor of thirty two, and the splitter 78 splits the frequency  $f_0$  of the fundamental pulse 52 by a factor of four, with the result that the corresponding frequencies  $f_1$ ,  $f_2$ , and  $f_3$  are filtered out by  
15 the filters 30', 30'' and 30''' respectively. The frequencies  $f_1$ ,  $f_2$  and  $f_3$  may be harmonics of the signals  $f_{10}$ ,  $f_{20}$  and  $f_{30}$  at the outputs of the switching means 80.

The components 74, 76, 78 and 80 identified by the  
20 reference numeral 28 may advantageously be replaced by an integrated logic circuit. The switching and splitting functions are in this case performed by flip-flops, AND gates, OR gates, EXCLUSIVE-OR gates, and further logic elements.

25

The splitter 34 has a switching means 82 that is connected to the input 56. The switching outputs of the switching means 82 are connected to a splitter 84 and a splitter 86. The output of the splitter 84 is connected to a shift  
30 element 88 and the output of the splitter 86 is connected to a shift element 90. The splitter 34 also includes a switching means 93 (triple on-off switch), whose switching outputs are connected to the filters 36', 36'' and 36'''. The shift element 90 is connected to a switching input, and  
35 the switching element 88 is connected to two switching inputs of the switching means 92. The switching elements of the switching means 82 and 92 can be controlled via the

microprocessor 50, the switching means 82 connecting the input 56 as desired to either the splitter 84 or splitter 86. The splitter 84 has a splitting factor of four, and the splitter 89 a splitting factor of thirty two, by means of which the frequency of the fundamental pulse 52 present at the input 56 can be split.

The shift elements 88 and 90 are connected via the inputs 58 and 60 to the fundamental pulse 52. The shift elements 88 and 90 are also connected via the inputs 66 and 70 to the trigger signal  $f_s$  (see Fig. 1) of the microprocessor. Corresponding to this trigger signal, the frequencies split via the splitters 84 and 86 at the input of the shift elements 88 and 90 respectively are shifted by exactly one fundamental pulse. This phase shift occurs at 2.929 kHz in the frequency range in the example in which the fundamental pulse  $f_0 = 60$  MHz. The frequencies  $f_{10}'$ ,  $f_{20}'$  and  $f_{30}'$  are thus digitally generated by means of the shift elements 88 and 90. The frequencies  $f_1'$ ,  $f_2'$  and  $f_3'$  are formed by filtering out the corresponding harmonics.

The components 82, 84, 86, 88, 90 and 92 identified by the reference numeral 34 may advantageously be replaced by an integrated logic circuit. The switching and splitting functions are in this case performed by flip-flops, AND gates, OR gates, EXCLUSIVE-OR gates, and further logic elements.

A phase difference measurement was used for illustrative purposes in the described embodiment. Other phase measurement methods, for example a null passage measurement, are obviously also possible.

## 5 Patent claims

1. Circuit arrangement for generating at least two signals of different frequencies, characterised in that at least one pair of frequencies having closely adjacent frequencies  
 10 ( $f_1$  and  $f_1'$ ,  $f_2$  and  $f_2'$ ,  $f_3$  and  $f_3'$ ) are derived from a frequency oscillator (fundamental pulse  $f_0$ ).

2. Circuit arrangement according to claim 1, characterised in that a trigger signal ( $f_s$ , 68) is used to generate  
 15 different, closely adjacent frequencies ( $f_1$  and  $f_1'$ ,  $f_2$  and  $f_2'$ ,  $f_3$  and  $f_3'$ ).

3. Circuit arrangement according to one of the preceding claims, characterised in that at least one of the signals  
 20 ( $f_1'$ ,  $f_2'$ ,  $f_3'$ ) is shifted by means of the trigger signal ( $f_s$ ) by a constant time interval predetermined by a fundamental pulse ( $f_0$ ).

4. Circuit arrangement according to one of the preceding  
 25 claims, characterised in that the trigger signal ( $f_s$ ) for generating at least two different frequencies ( $f_1$  and  $f_1'$ ,  $f_2$  and  $f_2'$ , and  $f_3$  and  $f_3'$ ) is generated by an oscillator of lesser accuracy.

30 5. Circuit arrangement according to one of the preceding claims, characterised in that at least one frequency ( $f_1$ ,  $f_2$ ,  $f_3$ ,  $f_1'$ ,  $f_2'$ ,  $f_3'$ ) is generated by filtering out harmonics from at least one frequency ( $f_{10}$ ,  $f_{20}$ ,  $f_{30}$ ,  $f_{10}'$ ,  $f_{20}'$ ,  $f_{30}'$ ) derived from the fundamental pulse ( $f_0$ , 52).

35

6. Circuit arrangement according to one of the preceding claims, characterised in that all frequencies ( $f_1$ ,  $f_2$ ,  $f_3$ )

are in each case shifted by exactly one frequency ( $f_4$ ) from the associated frequencies ( $f_1'$ ,  $f_2'$ ,  $f_3'$ ).

7. Circuit arrangement according to one of the preceding  
5 claims, characterised in that the circuit arrangement includes switchable splitters (28, 34) that can be controlled by means of a microprocessor (50).
8. Circuit arrangement according to one of the preceding  
10 claims, characterised in that the splitter (28) is designed to generate at least one frequency ( $f_{10}$ ,  $f_{20}$ ,  $f_{30}$ ) and the splitter (34) is designed to generate at least one shifted frequency ( $f_{10}'$ ,  $f_{20}'$ ,  $f_{30}'$ ).
9. Circuit arrangement according to one of the preceding  
15 claims, characterised in that the splitters (28, 34) have sub-splitters (76, 78, 80, 82) for generating multiple frequencies ( $f_{10}$ ,  $f_{20}$ ,  $f_{30}$  and  $f_{10}'$ ,  $f_{20}'$ ,  $f_{30}'$ ).
10. Circuit arrangement according to one of the preceding  
20 claims, characterised in that the splitters (28, 34) for generating as desired one of the frequencies ( $f_{10}$ ,  $f_{20}$ ,  $f_{30}$  and  $f_{10}'$ ,  $f_{20}'$ ,  $f_{30}'$ ) have switching means (74, 80, 82, 92).
11. Circuit arrangement according to one of the preceding  
25 claims, characterised in that the splitter (34) has shift elements (88, 90) for shifting by the frequency ( $f_4$ ), which elements can be controlled via a trigger signal from the microprocessor (50) and permit a shift of an input  
30 frequency by at least one fundamental pulse ( $f_0$ ).
12. Circuit arrangement according to one of the preceding  
claims, characterised in that filters (30, 36) for the band-pass filtering of signals with frequencies ( $f_{10}$ ,  $f_{20}$ ,  
35  $f_{30}$ , and  $f_{10}'$ ,  $f_{20}'$ ,  $f_{30}'$ ) are connected to the splitters (28, 34).



13. Circuit arrangement according to one of the preceding claims, characterised in that harmonics are filtered out from at least one of the generated frequencies ( $f_{10}$ ,  $f_{20}$ ,  $f_{30}$ ,  $f_{10}'$ ,  $f_{20}'$ ,  $f_{30}'$ ) by means of SAW filters (= surface wave filters).
14. Circuit arrangement according to one of the preceding claims, characterised in that the splitter (34) comprising the components (82, 84, 86, 88, 90 and 92) is realised by means of an integrated logic circuit.
15. Circuit arrangement according to one of the preceding claims, characterised in that the splitter (28) comprising the components (74, 76, 78 and 80) is realised by means of an integrated logic circuit.
16. Circuit arrangement according to one of the preceding claims, characterised in that the circuit arrangement (24) is used to generate modulation frequencies of laser signals (16) from a distance measuring instrument (10).
17. Circuit arrangement substantially as hereinbefore described with reference to the accompanying drawings.



Application No: GB 9904155.0  
Claims searched: 1-17

Examiner: Brian Ede  
Date of search: 14 July 1999

**Patents Act 1977**  
**Search Report under Section 17**

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:  
UK CI (Ed.Q): H3R(RMA)  
Int CI (Ed.6): H03B 21/02  
Other: Online: EPODOC; JAPIO; WPI

**Documents considered to be relevant:**

Category	Identity of document and relevant passage	Relevant to claims
X	GB 2128048 A (RACAL-DANA) see The Fig	1 at least
X	GB 2039441 A (TELEFONGYAR) The Fig	1 at least
X	GB 1420271 (SOC D'ETUDE ET D'APPLICATION DES TECHNIQUES NOUVELLES) see Fig 1	1 at least
X	GB 1348221 (MARCONI) see The Fig	1 at least
X	GB 1264770 (STC) see The Fig	1 at least
X	US 5107124 (SIEMENS) see CL, BG1, BG2 Fig 1	1 at least
X	US 4959654 (HONEYWELL) see 52, 501, 502 Fig 3	1 at least

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